Measuring and modeling soil intra-day variability of the 13CO2 & 12CO2 production and transport in a scots pine forest

Stephanie Goffin, Florian Parent, C. Plain, Daniel Epron, Christophe Wylock, Benoit Haut, Martin Maier, Helmer Schack-Kirchner, Marc Aubinet, Bernard B. Longdoz

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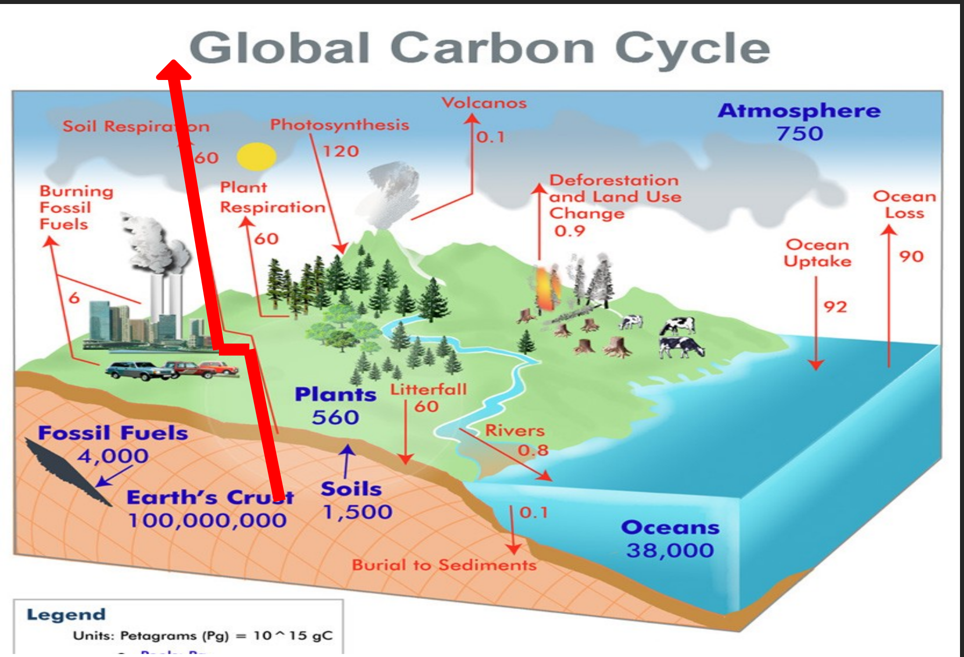
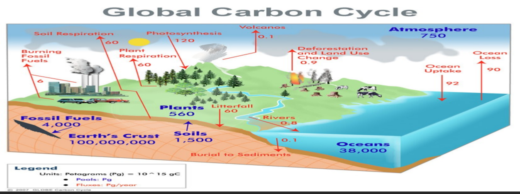
Background & Objectives

Soil CO2 efflux (Fs)





Fs: One of the largest component of C cycle

10 times greater than fossil fuel emissions

Soil: large C pool

Fs changes may rival the loading of atmosphere by fossil fuel

Uncertainties >>>

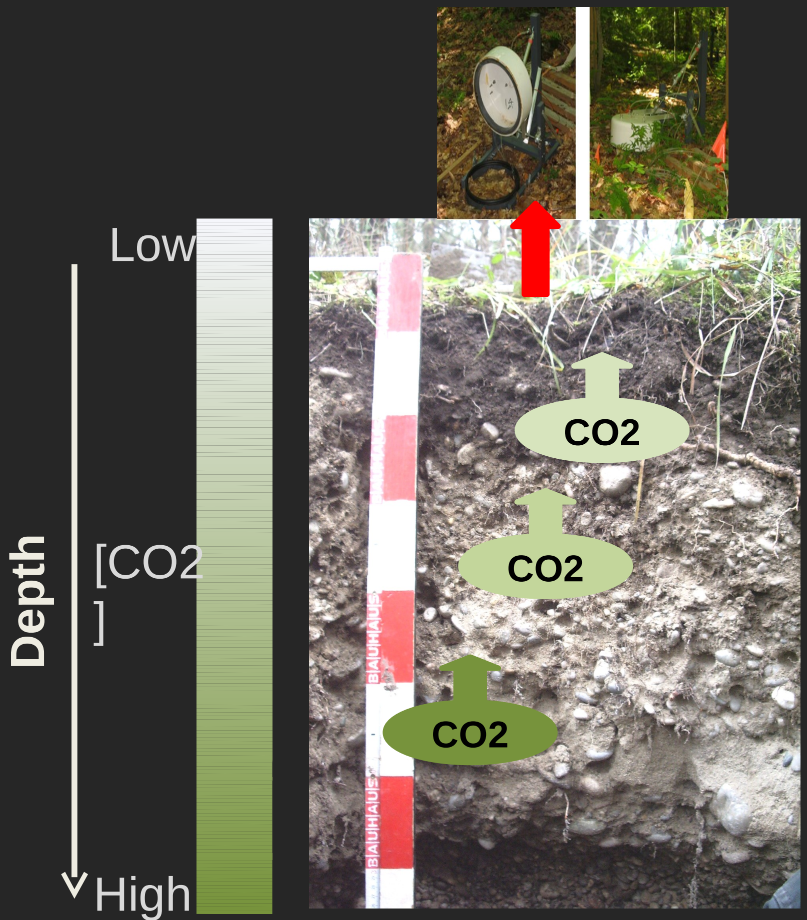
? Climate Change Impact?

? Positive feedback to the GHG effect?

Past | today | Future

Empirical description → Mechanistic understanding

Background & Objectives



Fs

Transport

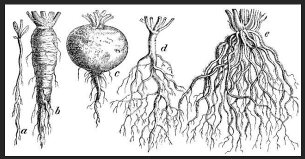
Diffusion

Avection +
Dispersion

Liquid phase

Production

Autotrophic

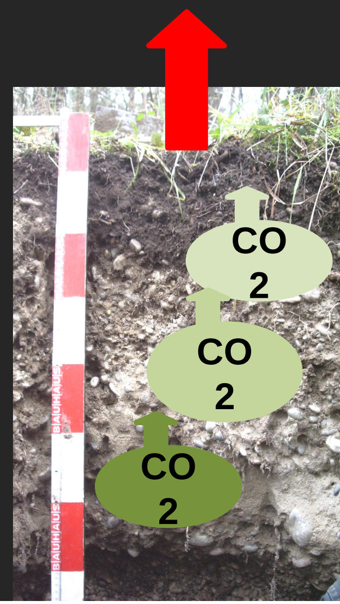


Heterotrophic

Abiotic

Background & Objectives

Fs



Transport

f(porosity, humidity…)

Production Ps

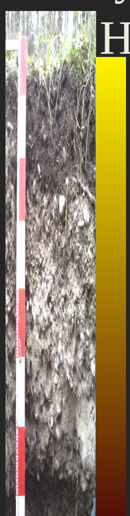
Heterotrophic

Autotrophic

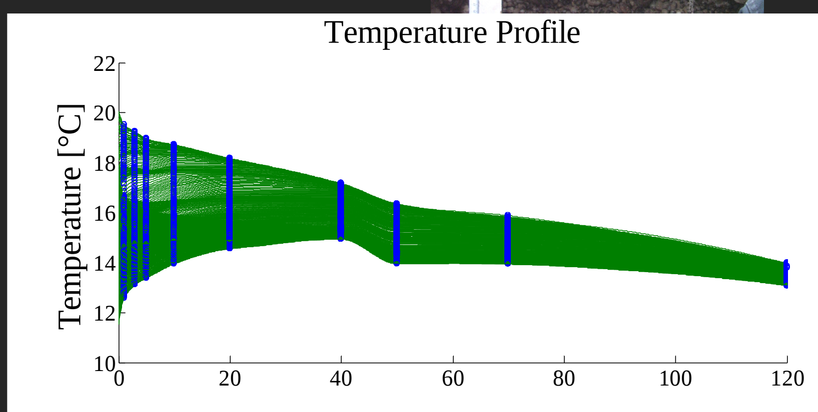
f(Temperature, humidity, substrate)

Porosity

High

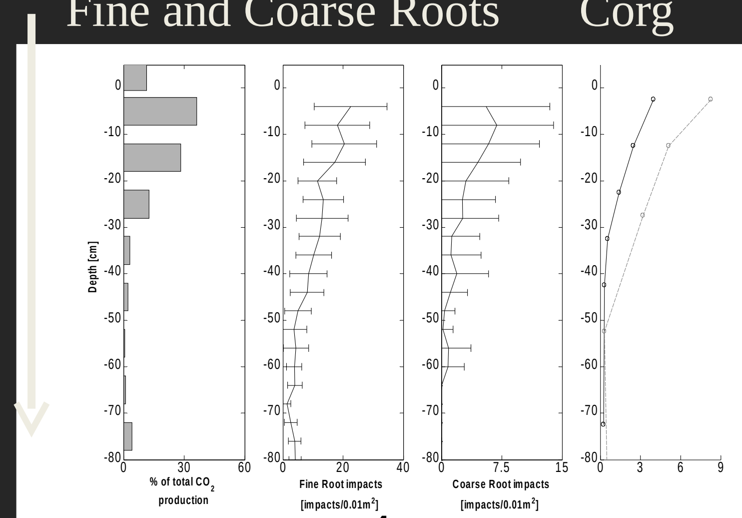


Low



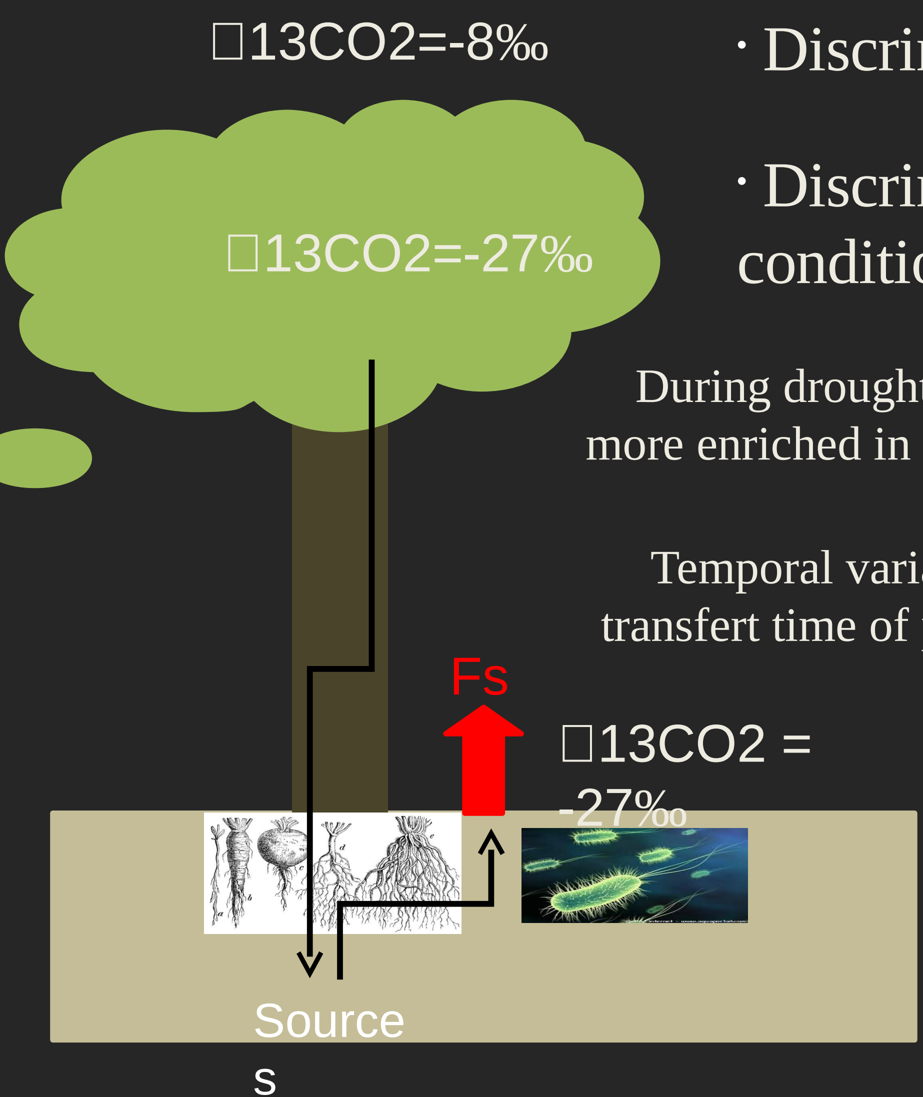
Fine and Coarse Roots

Corg



⇒ Multilayer Approach needed

Background & Objectives



· Discrimination during CO_2 assimilation

· Discrimination changes with climatic conditions

During drought, discrimination decrease photoassimilats more enriched in 13CO2 (ex: -25‰)

Temporal variation of 13CO2 may give informations about transfert time of photoassimilates

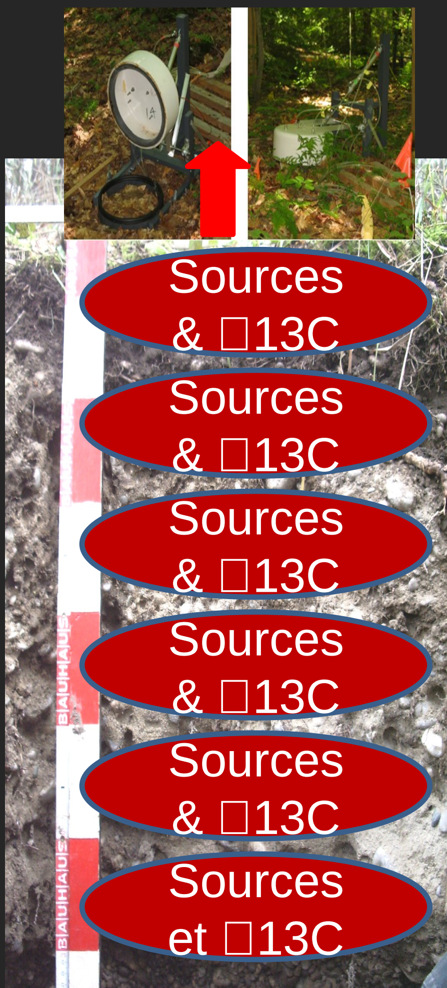
13CO2 may differs between CO2 sources

13CO2 may helps for partitionning Fs between sources

⇒ Understanding of δ13CO2 fluctuations (space & time) needed

Background & Objectives

Improving mechanistic understanding of Fs

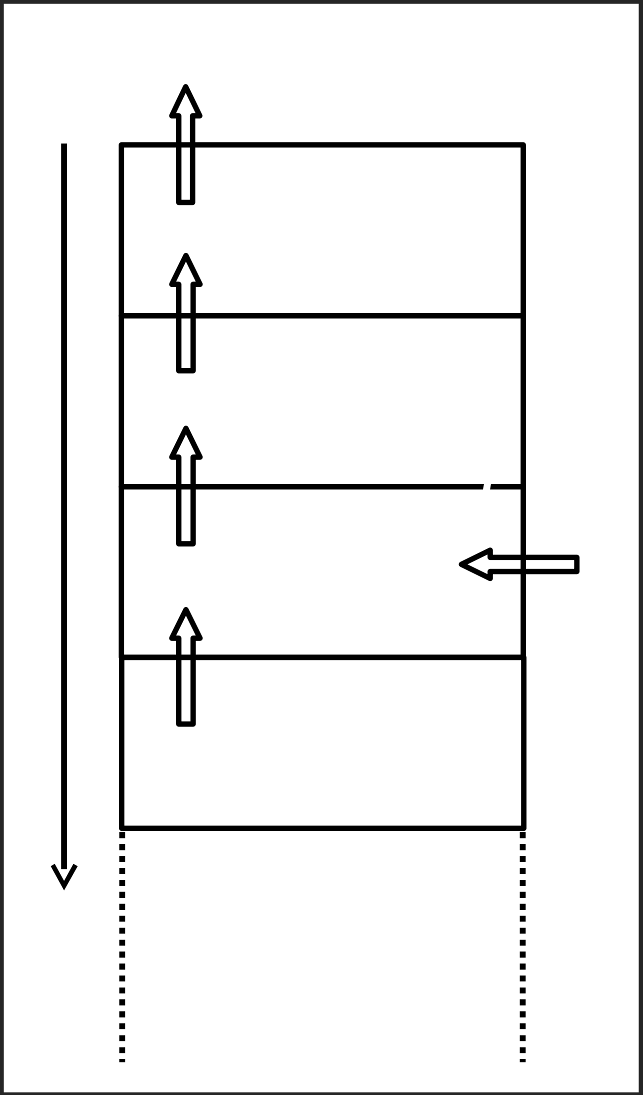


Multilayer Approach

Isotopic Signal Analysis

1) Determine the CO2 production rate ***Ps*** and its isotopic signature ***13Ps*** for the different soil horizons.
2) Find factors affecting ***Ps*** & ***13Ps*** intra & inter day fluctuations
3) Evaluate by modeling which processes (production or transport) drive ***Fs*** temporal variability

1. Determine Ps and δ13Ps for ≠ layers



- 12CO2 & 13CO2 balances for each i layer

$$\frac{\partial(\varepsilon_i * C_i)}{\Delta t} = \frac{F_{down} - F_{up}}{thick_i} + Ps_i$$ for 12CO2 & 13CO2

- Diffusive Flux-Gradient approach

$$F_x = D_{x\_i} * \frac{C_x - C_i}{z_x - z_i} = \left(D * \frac{\Delta C}{\Delta z}\right)_{x\_i}$$ for 12CO2 & 13CO2

$$\Rightarrow Ps_i = \varepsilon_i * \frac{\Delta C_i}{\Delta t} + \frac{\left(D * \frac{\Delta C}{\Delta z}\right)_{down\_i} - \left(D * \frac{\Delta C}{\Delta z}\right)_{up\_i}}{thick_i}$$

Vertical profile of their dependence on SWC measured on samples at

ALBERT-LUDWIGS-UNIVERSITÄT FREIBURG

12CO2 & 13CO2 vertical profile measured by

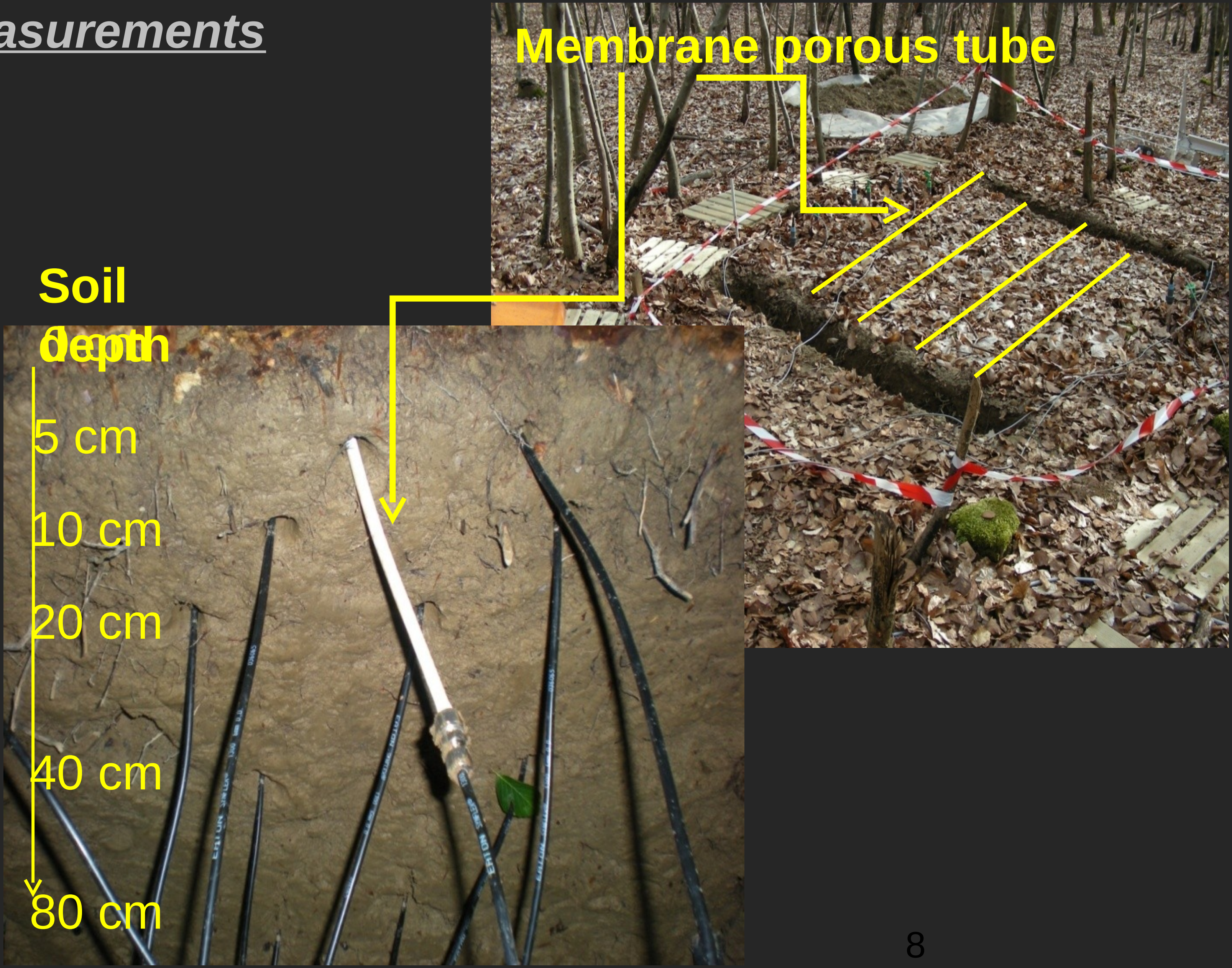
INRA SCIENCE & IMPACT

UNIVERSITÉ DE LORRAINE

➨ Ps and δPs for each layer

1. Determine Ps and δ13Ps for ≠ layers (Parent et al. 2013)

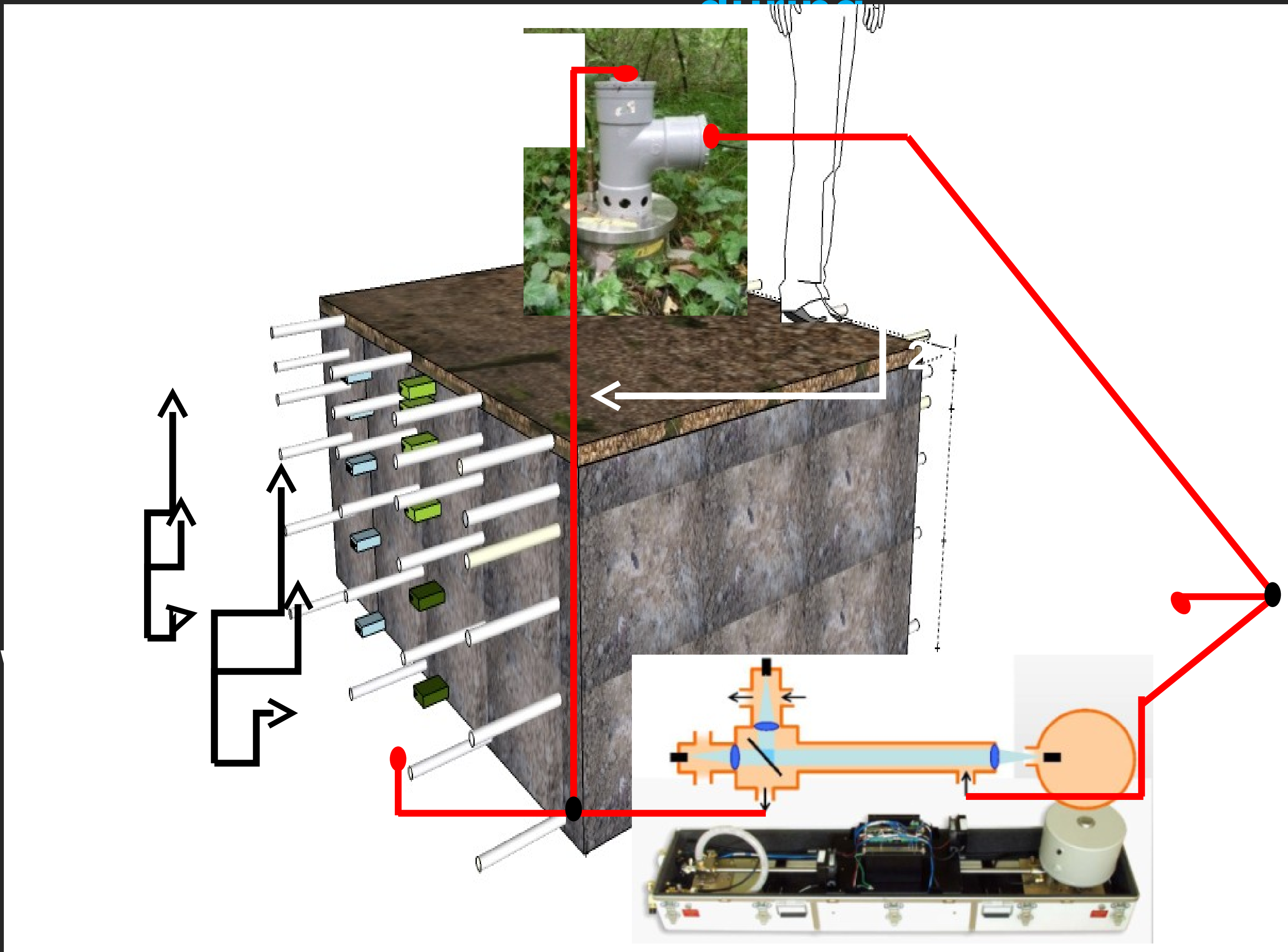
Field Measurements



1. Determine Ps and δ13Ps for ≠ layers (Parent et al. 2013)

Field Measurements

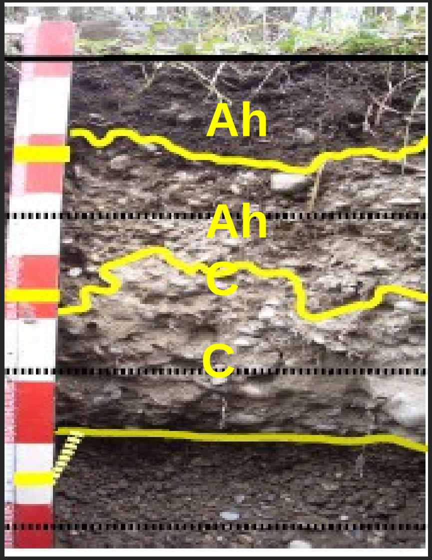
Half-hourly In situ measurements during 21 days



TDLS:
12[CO2] & 13[CO2]
1) membrane tube ≡ [CO2] & δ*13*CO2 in soil layers
2) from chamber ≡ *EFs* & *δ13EFs*

1. Determine Ps and δ13Ps for ≠ layers

Site Description



Hartheim experimental site

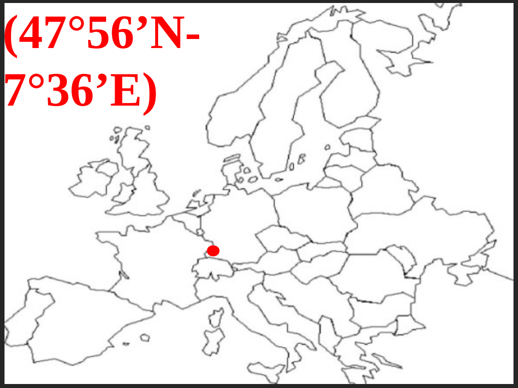
Slow growing 46 year old Scots Pine Forest (Pinus sylvestris L.)

Mean annual air Temp:10.3°C

Mean annual precip: 642 mm

Haplic Regosol (calcaric, humic) (FAO, 2006)

Humus type is mull (1-3 cm thick)

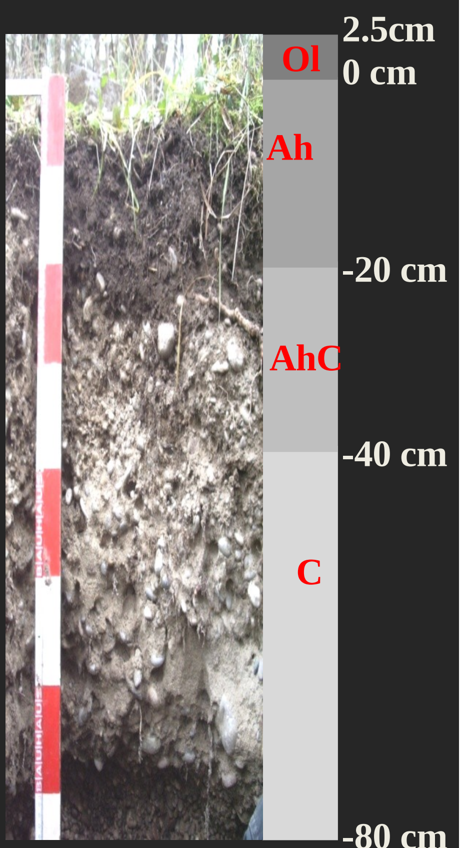


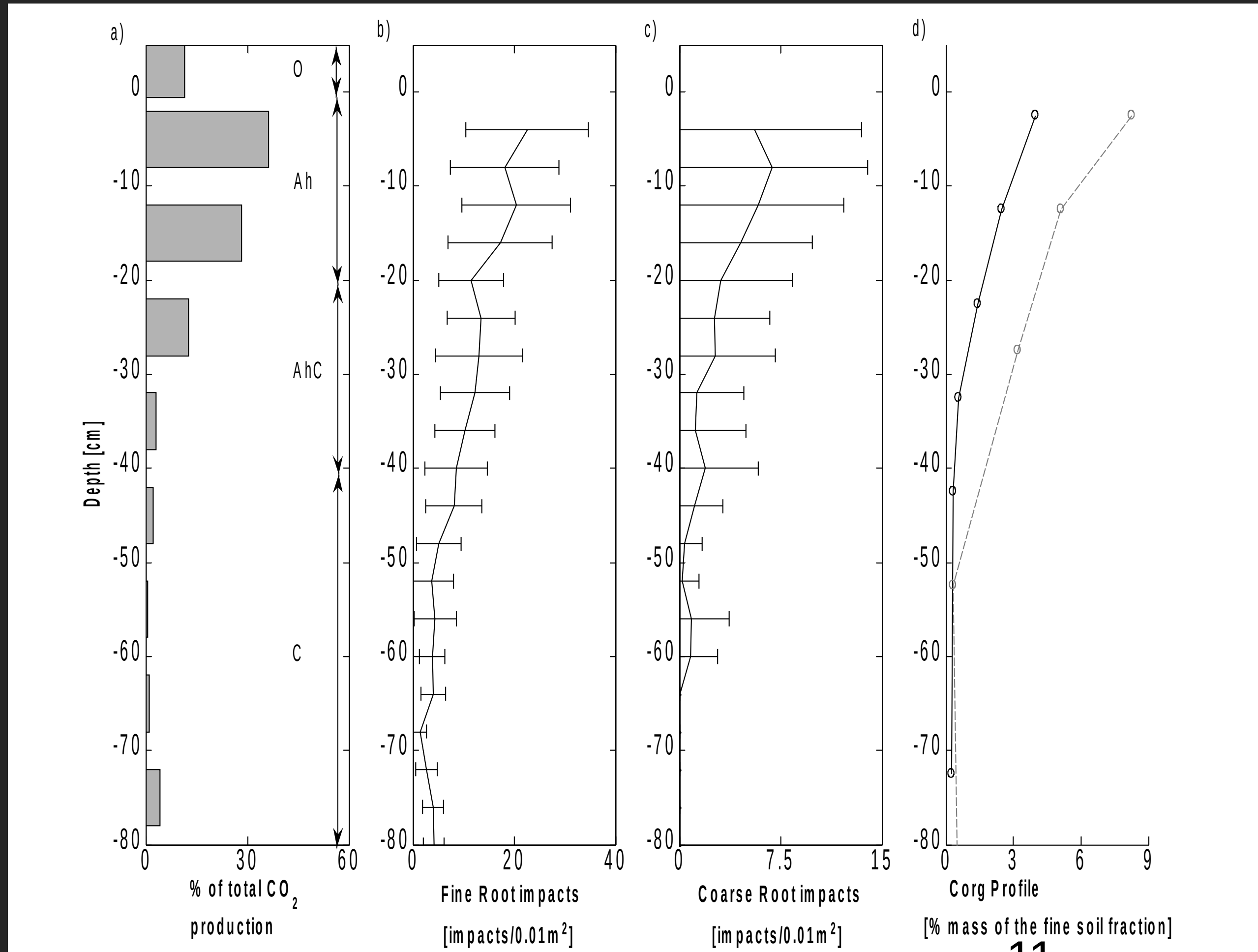
Eddy Covariance tower Meteorological station

1. Determine Ps and δ13Ps for ≠ layers

Vertical Profile of Ps

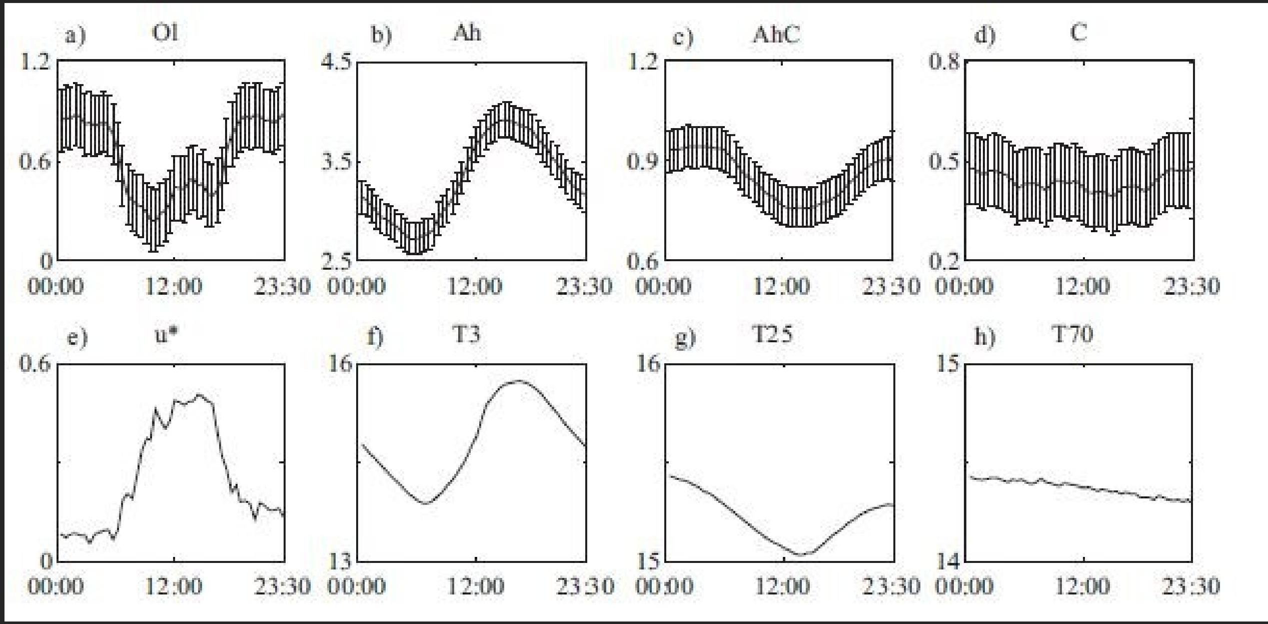
Horizon	% CO_2 Prod
Ol	11.5
Ah	64.7
AhC	15.8
C	8





2. Factors affecting Ps and δ13Ps (Goffin et al. 2014)

Intra-day Ps variability



Mean diel variation

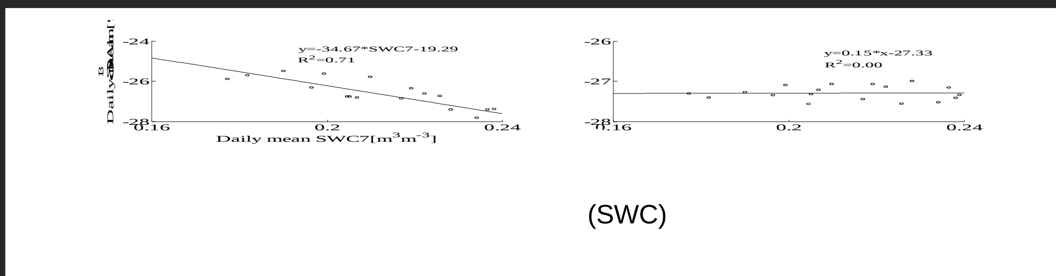
- Mean diel varation explained by **LOCAL T°** in Ah & AhC
- No significant diel variation in C
- In the litter relationship with u* because of advection not taken into account

$$Ps + Adv = \frac{d(\varepsilon * C)}{dt} + \frac{d}{dz}\left(D\frac{dC}{dz}\right)$$

2. Factors affecting Ps and δ13Ps (Goffin et al. 2014)

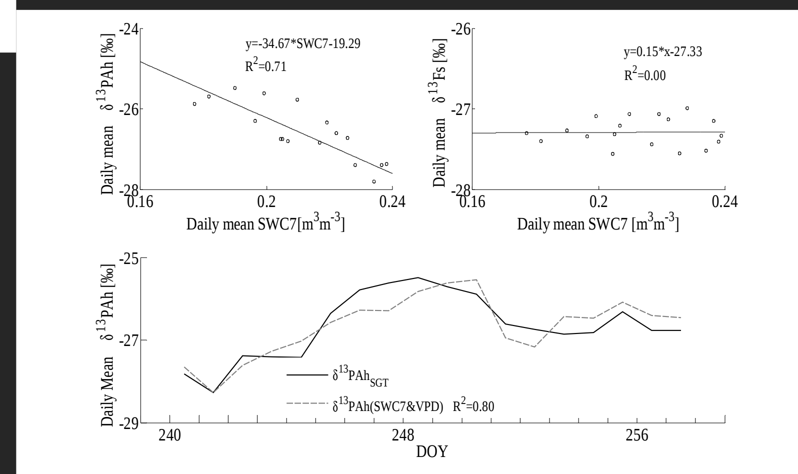
Inter-day δ13Ps variability

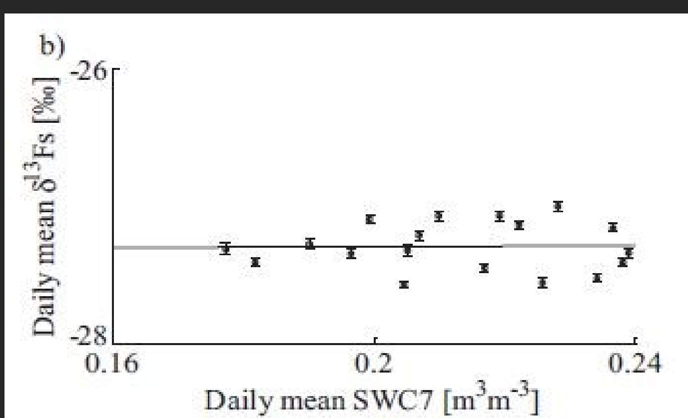
- **Significant day to day variations of δ13Ps (> 2.5‰) in Ah**



- **Best explained by soil moisture**

Soil drought impact = enrichment
Same impact as for photosynthesis discrimination !!!





- **Not observed with chamber efflux measurements**
  - Mixing of ≠ layers contributions
  - Perturbation of local soil climate by chamber ?

3. Who (transport or production) is responsible for Ps and δ13Ps temporal variability ?

(Goffin et al. undre review)

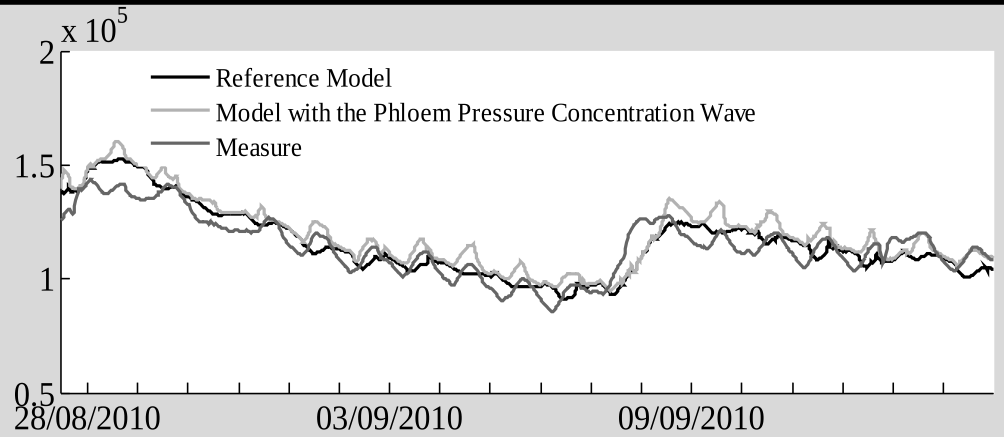
- **3 model versions simulating CO2 production and transport**
- **Comparison of their outputs with [CO2] and Fs measurements**

  - Reference model (RM):
    each layer produce CO2 following Q10 relationship with the local t° & diffusion is the only transport process
  - Transport Version (TV):
    Advection and dispersion are ss
  - Production Version :
    Production is also driven by Photosynthesis Pressure Concentration Wave (PPCW) by adding a dependence on VPD

3. # Who (transport or production) is responsible for Ps and δ13Ps temporal variability ?

(Goffin et al. undre review)

- RM: Relatively good reproduction of inter-day variability but intra-day variability too low and not in phase



- No significant improvement with TV
- PPCW : Not perfect but diurnal fluctuations are better reproduced and difference in phase is reduced

➡ **Working on production description instead on transport one is a better option to improve soil CO2 model**

Key points

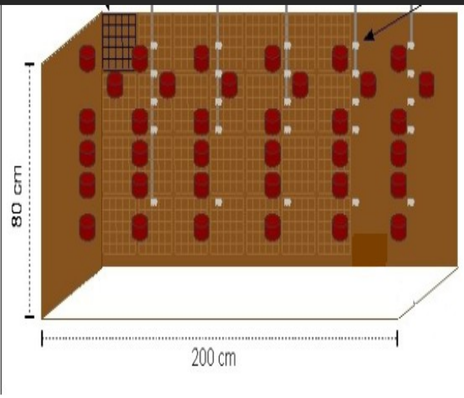
- Set up of an experimental *in-situ* device to obtain vertical profile of Ps and δPs
- Identify a dependence of one layer to local temperature
- Indentify enrichment of Ps with soil drought in Ah horizon
- Soil CO2 model should develop production description more than transport one to simulate hourly/daily variability

Thank you for your attention

Meet me on poster #21

Materials & Method

4. **Laboratory Measurements**

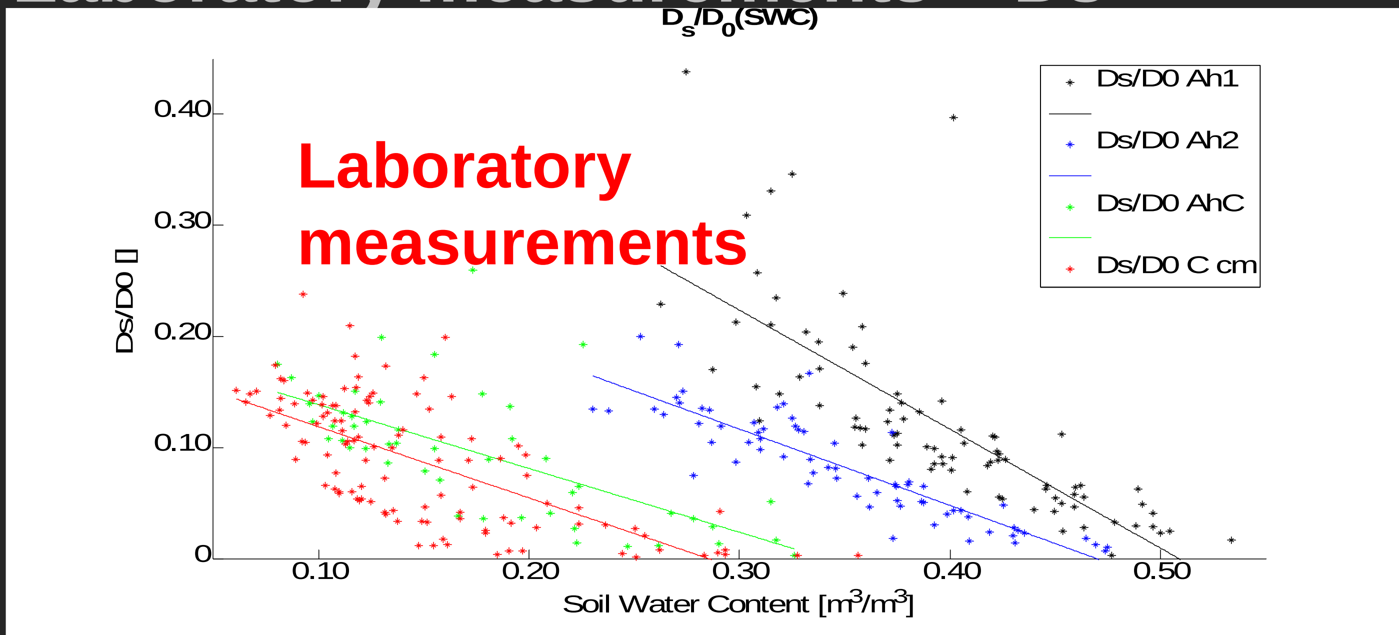


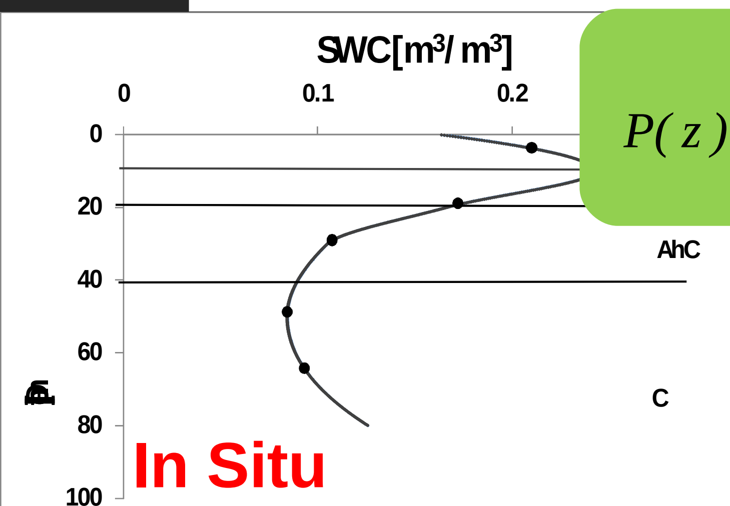
- Undisturbed soil cores of 200 cm3 collected in each horizon

- Soil horizon specific physical parameters :
  - Porosity, pF curves
  - Relationships between Ds(SWC)

Material & Method

4. Laboratory measurements – Ds

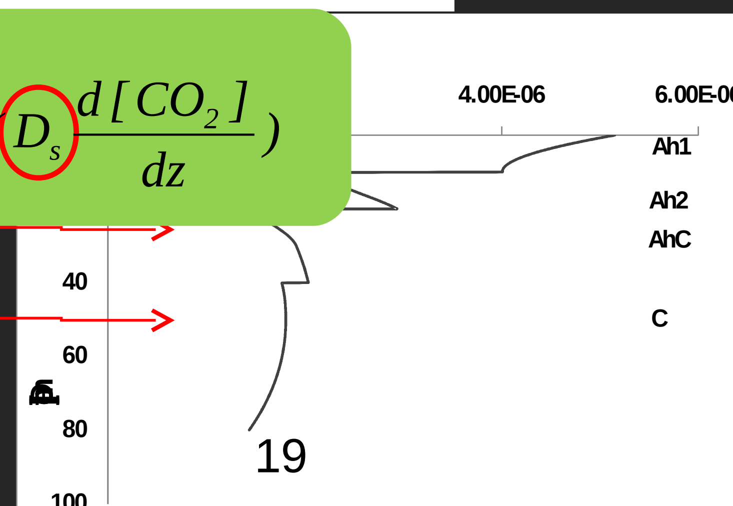




$$P(z) = \frac{d(\varepsilon[CO_2])}{dt} + \frac{d}{dz}\left(D_s \frac{d[CO_2]}{dz}\right)$$

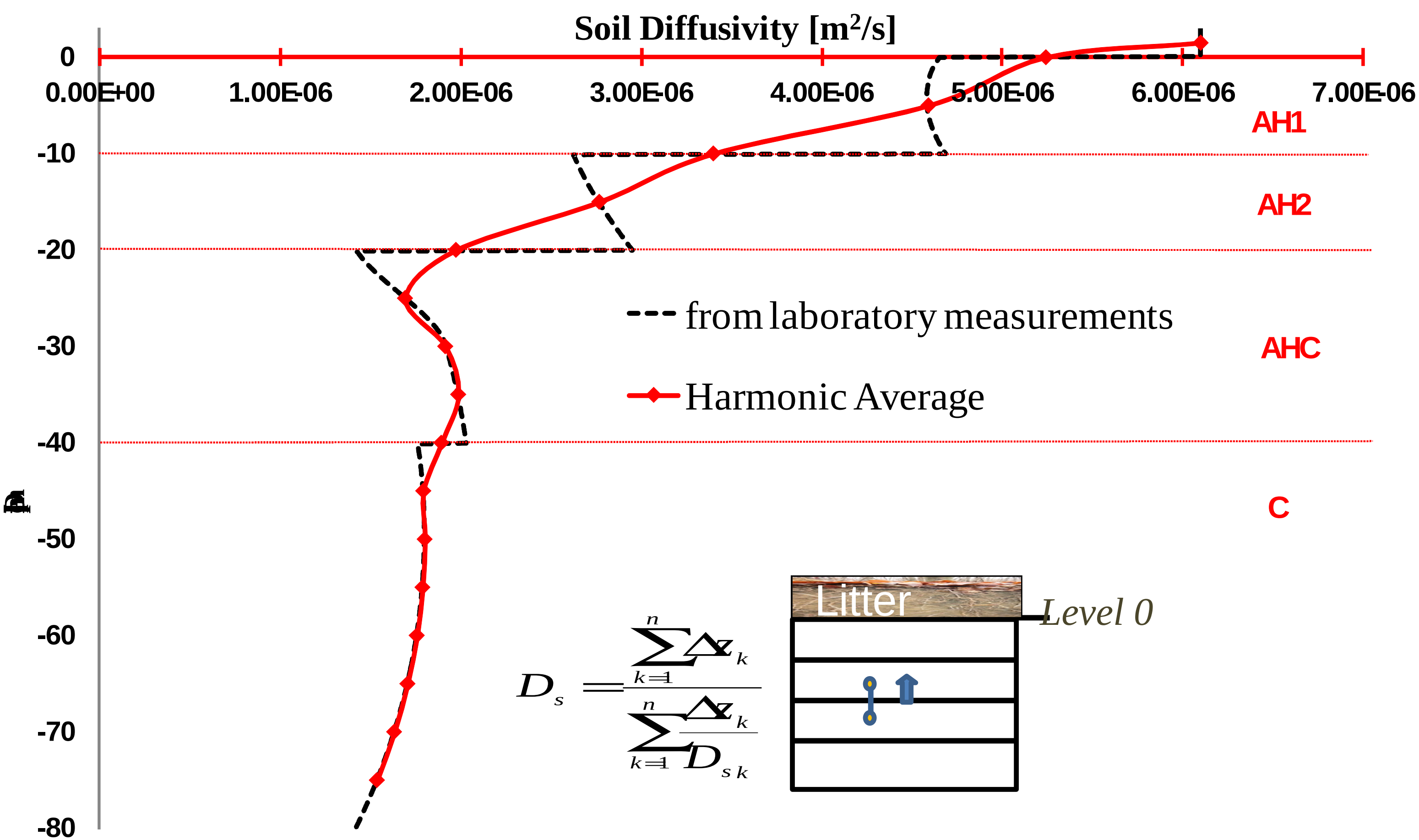
Ds(SWC)AhC

Ds(SWC)C



Materials & Method

4. Laboratory Measurements– Parametization



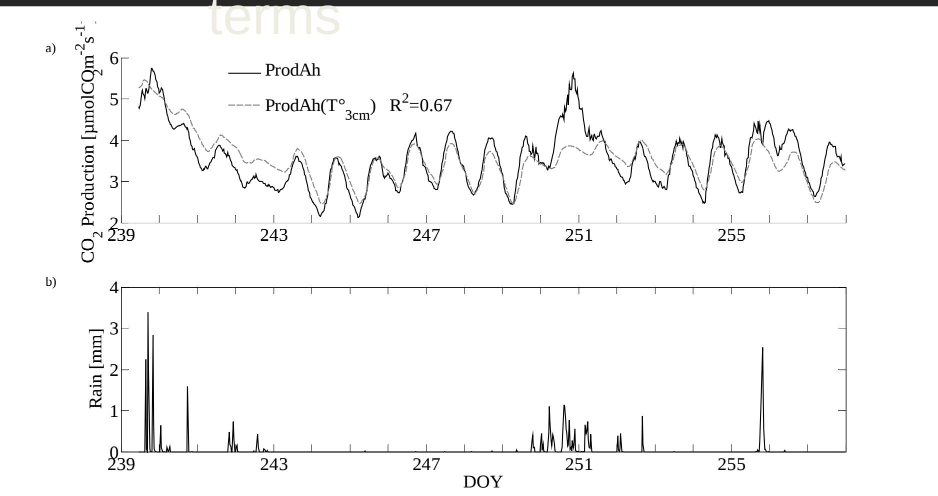
$$D_s = \frac{\sum_{k=1}^{n} \Delta z_k}{\sum_{k=1}^{n} \frac{\Delta z_k}{D_{sk}}}$$

1. Determine Ps and δ13Ps for ≠ layers

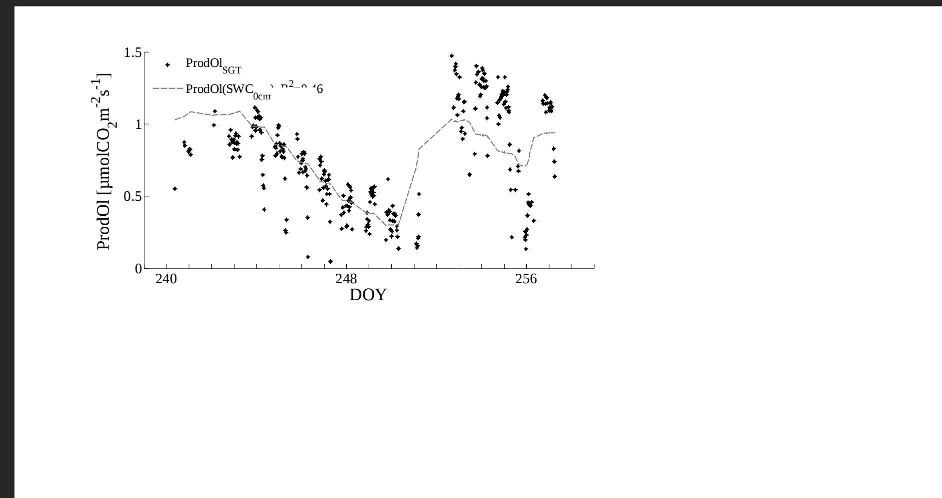
Day to day variation

Vertical Profile of CO2 sources

Ah Production terms



Litter Production terms



· Soil production shows clear diel and daily fluctuations in **Ah**

· The diel and daily fluctuations are best explained by the T measured in the topsoil
temperature is the most important driver of soil CO2 production

·Unlike other horizons, Ol production was best explained by surface soil water content (SWC) (R2=0.46)